Emission Reduction Research on Solar Hot Water System Project

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Abstract

Energy is nearly exhausted, and climate is changing seriously in current. On the road to vigorously develop energy conservation, and to seek clean and renewable energy in China, as a clean energy, the application of solar energy in buildings has been strongly developed and researched. In this paper, pollutant emission reductions, environmental benefits, economic benefits and social benefits of solar hot water system project of a residential area in Tianjin are calculated and analyzed. The mode of hot centralized collection and individual heating is used in this solar hot water system project. It can be seen that solar energy technology plays an important role in energy conservation and emissions reduction in China, and has a profound significance for promotion.

Keywords

Solar Hot Water System; Co_2 Emission Reductions; Pollutant Emissions; Economic Benefits; Energy Conservation and Emission Reduction

Introduction

With the features of large total amount, clean and non-polluting, and there is no depletion phenomenon, solar energy resource now has become one of the most important renewable energy. Since the 21st century, the utilization of solar energy technology has been widely developed. The utilization of solar energy technology is converting solar radiation into heat or electricity of two ways, one of the most important ways is converting the solar radiation into heat instead of the burning of fossil fuels, the technology in buildings includes heating, air conditioning, hot water and so on. The development and utilization of solar energy is an important aspect of building energy conservation, and it has made a great contribution to solve today's energy crisis, global warming and other issues.

The annual amount of solar radiation is 5152.363MJ/m^2, which in the lighting surface of the solar collector is 5966 MJ/m^2, the annual sunshine time is 2612.7 hours, so it has abundant solar energy resources in Tianjin. Therefore, in this background, this paper chooses the project of a residential area with the using of solar water heating systems to supply domestic hot water in Tianjin. By calculating the project emission reductions of greenhouse gases (CO_2) and air pollution, and the project internal rate of return, the paper analyzes the engineering practice in three aspects which are the environmental benefits, economic benefits and social benefits, respectively. Through the analysis, it can be seen that the solar hot water system has great benefits in each aspect, which is worth promoting, and it is an important mean to achieve energy conservation and emission reduction in China.

Solar Hot Water Project

A new residential area has been constructed in Tianjin, the total land area is 153,595.20 m^2, planning construction area is 153.600 m^2, the construction is small high-rises, the household is 2424, the estimated total resident population is 7757. Taking into account of the uneven using heat of residential users, and the problem of the difficult to charge for the hot water by the central heating, it uses solar water heating system for residential users providing domestic hot water in the area, whose mode is the latest hot centralized collection and individual heating.

With the mode of hot centralized collection and individual heating, the solar collector is centrally arranged on the roof of each building, as shown in figure 1. Water tank is set up in the roof, while solar thermal storage tank is installed in per household to separately provide hot water for the household. Heat collected by solar collectors is centrally stored in the tank which is in the equipment room on the roof, and uniformly delivered to storage tanks of every household used for heat transfer through the pipe network. In addition, in order to ensure to meet the 24-hour domestic hot water supply, water storage tank in each household added the electric auxiliary equipment. When the weather is better and sunshine is ample, heat collected by the solar collector can provide

FIG 1 THE LIVE-ACTION OF RESIDENTIAL SOLAR COLLECTORS

the heat required by the household, when it is lack of sunshine, the household can start the electric auxiliary heating equipment to meet the demand for the heat.

The SAMP heat pipe vacuum tube collector is used in the solar water heating system, its model is C3-SD1 * 8L, Dimension is Φ100mm × 2000mm, it mainly consisted by the heat pipe, the absorber plate, the glass tube, the metal end cap and the getter device and etc. By design, it is need to install 2984 collectors, the total collector area is over 3000 m², the heat gain efficiency of the collector is up to 60% -68%. The annual solar fraction of solar water heating systems is up to 65%. The water storage tank is installed in every household toilet, which is the 80L SAMP horizontal enamel interior tank. The 64 Germany Ville circulating pumps are installed, pump power is 800W, pump flow rate is 10-20 tons / hour, and pump head is 8-28m. When there is sufficient solar energy, the water in the collector is heated by solar radiation through the heat exchanger. When the water temperature reaches the set requirement, the hot water circulating pump begins to work, the hot water is delivered to the users' hot water tank for storage. Meanwhile, a 1.5KW electrical heating equipment is installed in the household hot water storage tank to meet the demand. When the water can not be heated by solar energy to the desired temperature, the user can open the electric heating equipment. The way of the system is fell into the freezing measures. When the pumps stop working, due to gravity, the water in the collector and circulation line will automatically fall back to the water tank, without the need for other energy. Solar water heater in the bathroom which is like to conventional electric water heater can be used under pressure, the user pays the water bill. It is quick and easy for the users [1].

Environmental Benefits

The data provided by the project owners shows that, there are 2,424 households in the district in total, the designed water consumption of households is 150L / d, the designed hot water temperature of Tianjin area is 50°C, the designed cold water temperature is 10°C[2]. The heat of the community year-round supply for domestic hot water can be calculated as follows:

$$HG = mc(T_2 - T_1) = 2.22 \times 10^{13} J \quad (1)$$

Where:

HG: Heat required by the community all-year-round supplying for domestic hot water, J;

m: Daily designed water consumption of every household, L/d;

c: Specific heat of water, 4186 J/(kg·℃).

T_1: Initial temperature of water, ℃;

T_2: Designed temperature of domestic hot water, can be selected according to the parameters of the design document, ℃;

The annual solar fraction of solar hot water system is up to 65%, and then the heat of the solar hot water system per year can be calculated as follows:

$$HG_W = 2.22 \times 10^{13} \times 65\% = 1.443 \times 10^{13} J \quad (2)$$

Where:

HG_W : The annual heat of the solar hot water system, J.

Compared with the project supporting hot water for the households with coal-fired boilers in Tianjin, the all-year-round solar energy hot water system supporting the energy can save a lot of coal, and the amount of coal saving can be calculated as (3),

$$M = \frac{HG_W}{NCV} = 720.10t \quad (3)$$

Where:

M : The amount of coal saving of the solar hot water system per year of the district, t;

HG_W : Heat of the solar hot water system per year of the district, J;

NCV : Lower order heat of coal, we select 27170kJ/kg based on coal quality

We can see that the district saves a lot of coal by using solar energy, so reduces a large number of emissions of the greenhouse gases and air pollutants. Emission reduction can be calculated as follows [3] .

1) Calculation of CO_2 Emissions Annually

$$ER_{CO_2} = M \times NCV \times EF_{CO_2} \times 10^{-12} = 1850.86t \quad (4)$$

Where:

ER_{CO_2} : CO2 emissions of the project activity, t;

NCV : The program lower order heat of coal, we select 27170kJ/kg based on coal quality;

M : The amount of coal saving of the project activity, t;

EF_{CO_2} : CO_2 emission factor of per unit coal, tCO_2e/TJ.

2) Calculation of the Soot Emissions Annually

$$ER_{soot} = \frac{M \times D \times P_{fa} \times (1-\eta_d)}{1-C_{soot}} = 0.24t \quad (5)$$

Where:

ER_{soot} : Soot emissions of the project activity, t;

M : The amount of coal saving of the project activity, t;

D : Dust content in the coal, %;

P_{fa} : Share that fly ash of soot accounts in the total ash, the value is relevant to the burning way, %;

η_d : The dust removal efficiency of coal-fired boilers and other equipments, %;

C_{soot} : Content of carbon in the soot, %.

(3) Calculation of Sulfur Dioxide Emissions Annually

$$ER_{SO_2} = 2 \times M \times S \times (1-\eta_S) = 0.71t \quad (6)$$

Where:

ER_{SO_2} : Sulfur dioxide emissions of the project activity, t;

M : The amount of coal saving of the project activity, t;

S : The share of combustible sulfur in coal, %;

η_S : The desulfurization efficiency of coal-fired boilers and other equipments, %.

4) Calculation of NOX Emissions Annually

$$ER_{NO_X} = 1.63 \times M \times (N \times \beta + 0.000938) = 5.21t \quad (7)$$

Where:

ER_{NO_X} : NO_X emissions of the project activity, t;

M : The amount of coal saving of the project activity, t;

N : The content of Nitrogen in the coal, %;

β : Nitrogen conversion rate in the coal, %.

TABLE 1 EMISSION REDUCTIONS（UNIT：T）

Types	Reductions
CO_2	1850.86
SO_2	0.71
NO_X	5.21
Soot	0.24
CO	32.92

5) Calculation of CO Emissions Annually

$$ER_{CO} = 2.33 \times M \times C \times \omega = 32.92t \quad (8)$$

Where:

ER_{CO} : CO emissions of the project activity, t;

M : The amount of coal saving of the project activity, t;

C : The content of carbon in the coal, , %;

ω : The incomplete combustion of the coal, %.

So we can get the emission reductions of greenhouse gases and air pollutants every year though calculation, the results show in table 1.

Economic Benefits

According to the data report of the project, we can see the economic parameters of the project, detailed data are showed in table 2[4].

According to the data from table 3.1 , it can be calculated that this project can recover the cost in eight years, the internal rate of return (IRR) with or without CERs income in operation lifetime , can be seen in table 3[5].

During the operation period, with the rising prices, energy shortage, electricity bill and income may change. With the use of the system, Maintenance expenditure will also be increased. So in the paper, three parameter factors are considered in the following sensitivity analysis, they are annual income, annual operation and maintenance cost, and initial investment. The IRR of the proposed project (without CERs revenue) varies to different extent, as shown in table 4 and figure 2.

TABLE 2 ECONOMIC PARAMETERS OF THE PROJECT

Parameters		Unit	Value	Source
Total Investment		10000 Yuan	1076	Project Data Report
Operation Lifetime		Year	15	Project Data Report
O&M Expenditure		10000 Yuan/Year	174.14	Project Data Report
CERs Price [4]		$US/tCO2	7	China CDM Information Centre
Annual Economic Income	Without CERs	10000 Yuan/Year	314.15	Project Data Report
	With CERs	10000 Yuan/Year	322.22	Statistical Calculation

TABLE 3 COMPARISON OF FINANCIAL INDICATOR IRR WITH AND WITHOUT CER REVENUE

Parameters	Unit	Without CERs	With CERs	Baseline IRR
IRR	%	9.82	12.05	8

TABLE 4 SENSITIVITY ANALYSIS ON IRR OF THE PROJECT ACTIVITY

Range of Variation	-5%	-2%	0	2%	5%
Annual Income	7.82%	9.03%	9.82%	10.59%	11.73%
Annual O&M Cost	10.89%	10.25%	9.82%	9.38%	8.72%
Initial Investment	10.73%	10.17%	9.82%	9.48%	8.98%

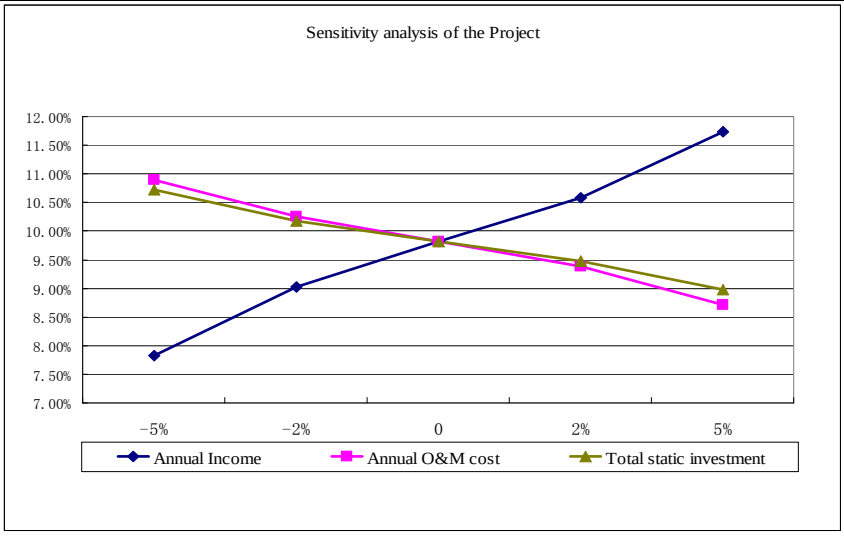

FIG 2 SENSITIVITY ANALYSIS OF THE PROJECT

Social Benefits

Hot centralized collection and individual heating is used in this solar hot water system in the district. Based on the last two sections of the economic benefits and environment benefits analysis, the annual average energy conservation rate can reach 65%, and it can reduce the amount emissions of greenhouse gases and air pollutant during the lifetime. At the same time, if CO2 emissions of this project can be traded in carbon market, it can also get a substantial amount of income. The implementation of this project not only solves the problem of household hot water using, but also reduces the use of fossil energy, reduces greenhouse gas emissions for the country, for the community. Meanwhile, the project has a lot of bright spots, and whose implementation brings huge social benefits.

(1) Although the initial investment is great, but the later running costs is smaller. Solar collectors are combined with roof slope perfectly. It is not only to ensure the appearance of building facades, but also to ensure the efficiency and safe operation of the collector. During the lifetime of the solar equipment, electricity savings is far exceeding the cost of the products households pay for. For the households, the consumption of conventional energy is reduced, heat utilities expenses is reduced, and it is more convenient to use, around environment is cleaner, households live more enjoyable. For residential investors, the residential quality is improved because of the design, it is not only response to the government policy of energy conservation, but also increases the selling point, achieves return on investment, it can be said to achieve a "win-win. "

(2) The design of the solar hot water system is innovative, traditional hot centralized collection and centralized heating is broke. The running mode of hot centralized collection and individual heating is used, which solves the long and embarrassing situation that it is difficult to install solar for the high-rise residential. After many arguments, hot centralized collection and individual heating is proved to be a scientific and feasible green energy program. It can be said that the successful application of the demonstration project has set off construction boom which is a wave of high-rise residential building integrated solar energy project.

(3) In recent years, because of country's mandatory requirement on energy efficiency of new constructions, when the engineers are designing, the most headache problem is how to achieve energy saving. At the same time the solar energy equipment manufacturers are also actively exploring products that are energy conservation and environmental protection. In this project, designers and solar energy equipment manufacturers make concerted effort in designing this system, energy conservation design concept of the engineers has been achieved, the more outstanding, applicable solar products are introduced by the solar energy equipment manufacturers.

(4) If CO_2 emissions of the project are certified to produce CERs, through the previous calculation, income can be increased. At the same time, it provides help to the achievement of the national energy-saving emission reduction targets. The construction industry is a high energy-consuming industry, the successful development of the project has a very great project promotion prospects.

Conclusions

Energy is exhausted, and climate is changing seriously in current. On the road to vigorously develop energy conservation, and to seek clean and renewable energy in China, as a clean energy, the application of solar energy in buildings has strong development and research. In this paper, pollutant emission reductions, environmental benefits, economic benefits and social benefits of solar hot water system project of a residential area in Tianjin are calculated and analyzed. The mode of hot centralized collection and individual heating is used in this solar hot water system project. By calculation, it can save 720.10 tons coal in this project every year, so that CO_2 emissions annually is 1,779.56t, SO_2 emissions is 0.71t, NO_X emissions is 5.21t, CO emissions is 32.92t, soot emissions is 0.24t. At the same time, by the internal rate of return and sensitivity analysis, IRR of this project including environmental benefits is 12.05%, with a strong economic attraction. Energy are saved, emissions are reduced in the project. Whether for households or the state and society, it has enormous social benefits. Thus it can be seen, the solar energy as a new clean energy, its technology will be an important technology in the future. It provides an important means for our country's energy conservation and emission reduction, fighting climate change and sustainable development.

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